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A PRELIMINARY EVALUATION OF THE PERFORMANCE OF SUPER-INSULATED DEMONSTRATION HOUSES BUILT IN THE KEEWATIN, NORTHWEST TERRITORIES

Development Evaluation Group
Canada Mortgage and Housing Corporation

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INTRODUCTION AND ACKNOWLEDGEMENTS

This preliminary evaluation is based on work done up to April 1982. A final field inspection will be made in the fall of 1982 in order to examine the performance of the foundations after the summer thaw, and to complete the collection of other data. It is unlikely that there will be major changes to the information presented in this report.

The monitoring of these houses was undertaken by Scanada Consultants Ltd., with Mr. Chris Milne as principal consultant, and this report was prepared by Nils Larsson, O.A.Q.. We gratefully acknowledge the cooperation of the occupants of all the houses tested, the local Housing Associations, the Keewatin Federation of Housing Associations, and the staff of the NWT Housing Corporation.

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SUMMARY

Seven Demonstration houses were built by the NWTHC in the Keewatin district of the Northwest Territories during 1981. The Demonstration houses were intended to display improvements in thermal performance and in their ability to provide heat and water during power outages. An existing unit type, known as the Woolfenden, was used as a baseline for performance assessments. It should be realized that, while the Woolfenden type has been widely built in the NWT during the past few years and therefore represents a current norms of construction in the NWT context, it represents a level of thermal performance which would be considered very high in the southern areas of Canada.

Four Demonstration houses and eight Woolfenden houses were selected in four Keewatin communities for the evaluation. Tests were carried out to ascertain the comparative thermal performance of building envelopes, the efficiency of heating systems, and to determine foundation stability. Assessments were also made of the effectiveness and efficiency of the air-to-air heat exchanger and the non-electric water system of the Demonstration units.

Testing of thermal performance indicated that the Demonstration units experienced a 14% improvement in envelope heat loss performance whereas the expected improvement was 34%. The difference appears to be primarily due to high rates of air infiltration and exfiltration through the heat exchangers and space heaters.

With respect to other features assessed:

- The airtightness of both unit types was relatively high, except for uncontrolled leakage through the Demonstration heat exchangers.
- The gravity-fed space heaters used in the Demonstration units were inefficient.
- Demonstration heat exchangers worked very poorly, due to faulty installation.
- The gravity water feed used in Demonstration units resulted in less-than-adequate water pressure due to insufficient head.
- Foundation settlement tests remain to be completed.
- The sunporch is well accepted by residents. Its annual solar performance could not be assessed because of winter sun conditions.
- Preliminary cost data indicate that the construction cost of the Demonstration units is likely to be lower than for the Woolfenden.

The evaluation of relative performance was made difficult because of technical problems in testing and because of differences in configuration and other aspects of the two house types. It seems clear, however, that the two-storey configuration is one which is a useful addition to northern housing forms and that most of the specific improvements tested are worthwhile pursuing, even if some of them require further development.

BACKGROUND AND PURPOSE OF THE DEMONSTRATION

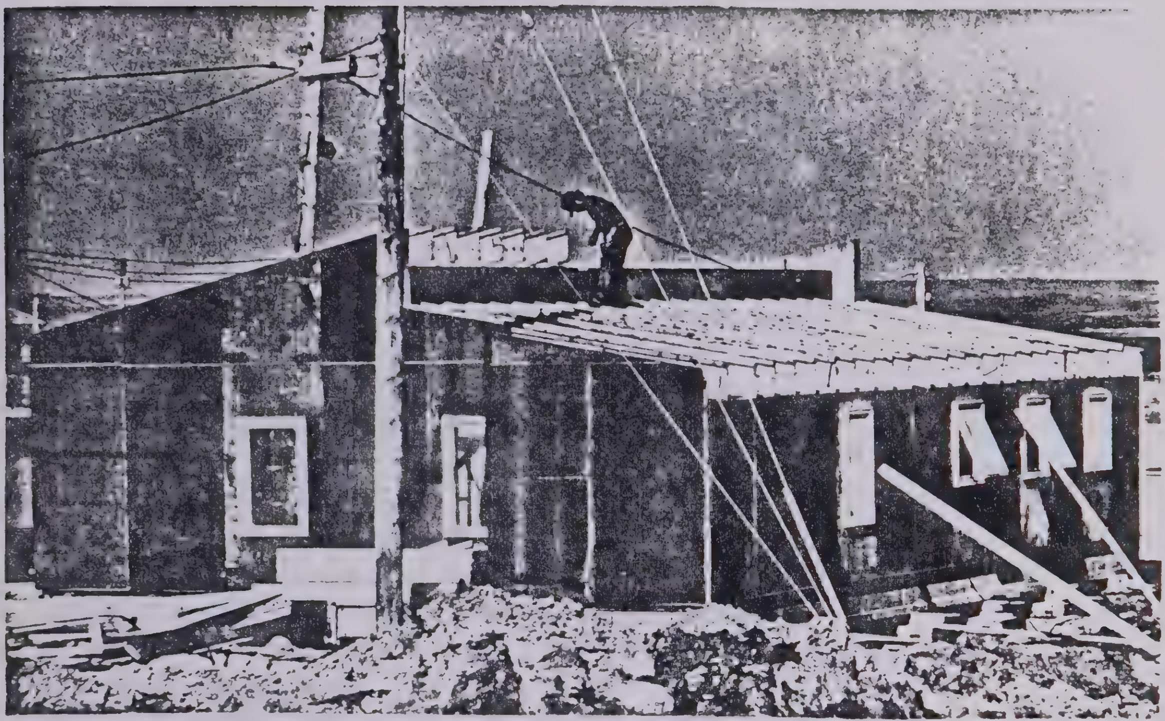
The Northwest Territories Housing Corporation (NWTHC) has recently designed and built demonstration housing units in seven Keewatin communities. The underlying idea was to design, in conjunction with the Keewatin Federation and local associations, a house which would be suited to Northern ways of life, be highly energy efficient, and enjoy a measure of autonomy from community services in case of a temporary power failure.

Canada Mortgage and Housing Corporation financed the construction of these units under its Public Housing Program, and CMHC was asked by the NWTHC to evaluate the performance of the features included in the units. A grant was obtained from the Department of Energy, Mines and Resources and a consultant was contracted to carry out a program of monitoring. Although the work is still going on, some preliminary results are available.

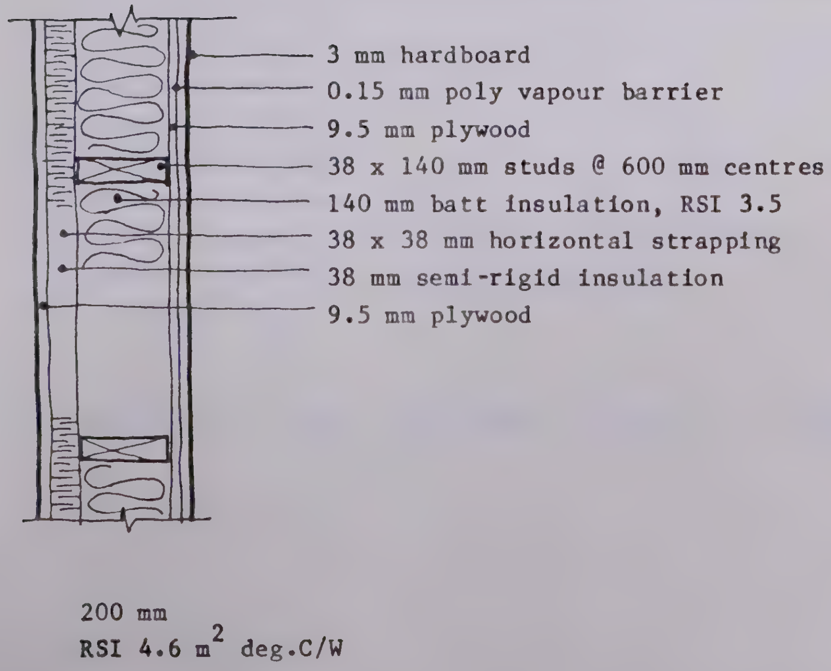
EXISTING HOUSING TYPE - THE WOOLFENDEN UNIT

The performance of housing must be evaluated in a comparative way, with the performance of new housing types being compared to that of existing, or control units. In this case, the controls chosen were a type of a house which has been widely built in the north over the last few years, commonly known as the Woolfenden type (see page 6 for photo and sketch).

In general terms, the Woolfenden control unit is a single-storey detached house, available in both three and four bedroom variants. The unit differs from similar houses built in the South in its use of prefabricated and stressed-skin exterior wall panels, a wood raft foundation and an emphasis on high thermal resistance in walls, roof and floor. The Woolfenden is a recent design and minor design differences between the 1980 and 1981 versions indicate that it is still evolving. In the evaluation, seven of the 1980 units and one of the 1981 units were chosen as control units. A more complete description can be found in Table 1, which also provides a comparative description of the Demonstration Units.



PLAN SECTION OF WALL, 1980 WOOLFENDEN HOUSE


3 mm hardboard
0.15 mm poly vapour barrier
9.5 mm plywood
38 x 140 mm studs @ 600 mm centres
140 mm batt insulation, RSI 3.5
38 x 38 mm horizontal strapping
38 mm semi-rigid insulation
9.5 mm plywood
200 mm
RSI 4.6 m2 deg.C/W

THE DEMONSTRATION UNITS

The Demonstration units were designed to provide an alternative design solution to the problems which are unique to the north: the harsh environment, permafrost, shipping difficulties, the problems of maintenance and the desirability of a higher degree of independence from the electric power utility. This unit was also intended to be more suited to the style of living of northern peoples, taking into account such factors as the pattern of extensive and long-term visiting between households, and storage requirements for bulk foods, and the storage and maintenance of hunting equipment, snowmobiles and the like.

The units are two-storey detached houses[1], a shape which exposes less exterior surface area than does a bungalow of the same floor area. An unheated sunporch on the south side was designed to act as a buffer against cold winds, to provide storage space and to serve as an unheated vestibule outside the main door. It was expected that the sunporch would also provide solar heat gain to the main part of the house during spring and fall months. Most of the windows of the main house face south, a feature intended to reduce heat losses.

The heavily insulated walls, ceiling and floor of the Demonstration unit reflect current concerns to reduce heat losses. The careful installation of vapour barriers was also a priority, so that the heat loss and moisture damage often caused by the migration of airborne water vapour into the insulation and structure would be minimized. The natural consequence of a large amount of insulation is a thick wall, and this permitted the designers to establish rigid joints at floors and roof, so that the usual problems caused by possible movement of the foundation could be reduced. The foundation itself is a continuous-span laminated beam system resting on a gravel pad.

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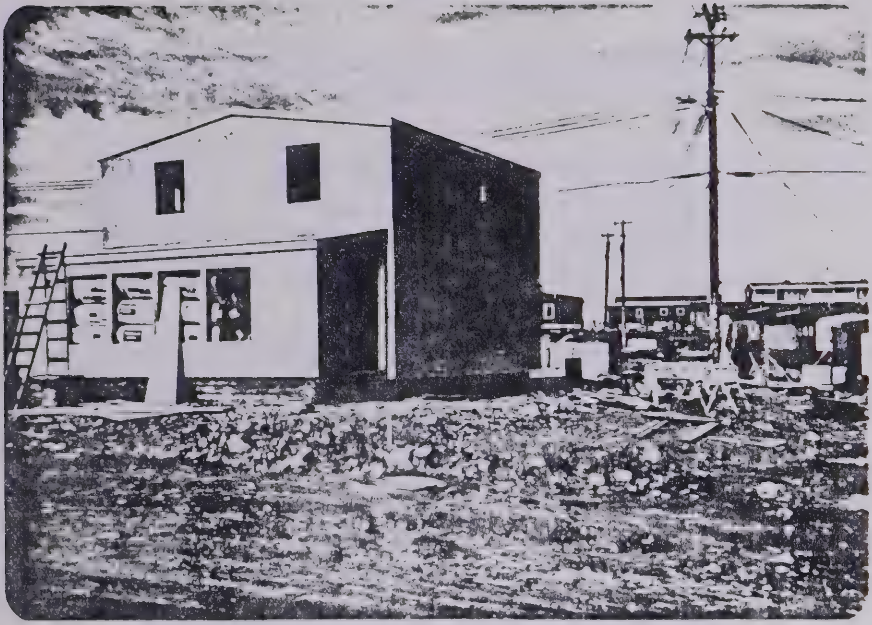
[1] See page 9 for photo and sketch, and Table 1 for further description

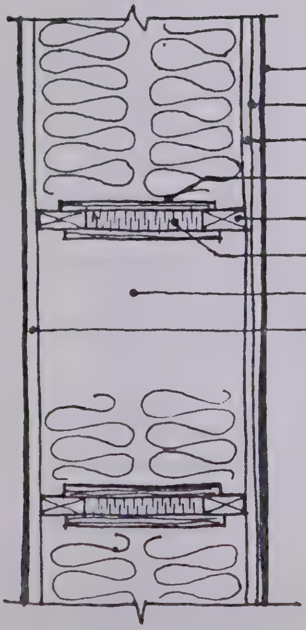
The heating system, an oil-fired and gravity fed space heater, was intended to provide a measure of independence from the local power utility when outages occur. Outages are not frequent, but when they do occur the result can be costly damage to the house and extreme inconvenience to the residents. A manually controlled electric fan circulates the heated air from the top of the second floor, down through a duct to a second floor plenum, then out through the ground floor ceiling.

Hot water is provided by an oil-fired heater which, although less efficient, is cheaper to operate than an electrical model. Both cold and hot water systems were intended to operate on a gravity feed system, thereby ensuring operation during power outages.

A heat exchanger was included in the design to remove warm, stale air from the bathroom and kitchen while heating the incoming cold fresh air.



PLAN SECTION OF WALL, DEMONSTRATION HOUSE



3 mm prefinished hardboard panel
0.15 mm poly vapour barrier
13 mm gyplap drywall
Gusset plate
38 x 63 mm studs @ 600 mm centres
38 x 174 mm rigid insulation
2 x 150 mm batt insulation, RSI 7.04
16 mm T & G exterior wall sheathing

332 mm
RSI 7.04 m^2 deg. C/W

THE RESEARCH

Four Demonstration houses and eight conventional houses, used as controls, were selected in the following communities:

Rankin Inlet: 1 Demonstration, 1 1980 Woolfenden, 1 1981 Woolfenden
Baker Lake : 1 Demonstration, 2 1980 Woolfenden
Whale Cove : 1 Demonstration, 2 1980 Woolfenden
Eskimo Point: 1 Demonstration, 2 1980 Woolfenden

The pairing of Demonstration units with Woolfenden units in the same communities minimized the effect of faulty or missed readings. Most of the Woolfenden houses chosen were 4-bedroom types which are slightly larger than the Demonstration units. All the houses chosen for testing were equipped with meters to measure consumption of fuel oil and electric power, and residents of the test units took temperature readings and meter readings on a regular schedule.

The research carried out by the consultants included the following specific tasks.

a) Actual fuel consumption was monitored in both unit types, using meter readings for oil and electrical consumption.
b) Heat losses were measured in both unit types during an overnight period, using portable electric heaters. This technique ensured that variations in the efficiency of the permanent heating systems would not be a factor.
c) The efficiency of the permanent heating systems was assessed in both unit types.
d) Building envelopes (walls, roofs and floors) were tested for degree of airtightness in both unit types.
e) Tests were carried out for the accumulation of moisture in the wall and ceiling membranes in both unit types.
f) The stability of the Demonstration Unit foundations were assessed by measuring the amount of settlement relative to fixed benchmarks. This component of the research will be completed during 1982.
g) The efficiency of the Demonstration heat exchanger was assessed.
h) The Demonstration unit gravity water system was assessed.

In addition to these specific tasks, observations were made by the consultants and by some residents about the suitability of the two-storey configuration, the sunporch and other aspects of the design of the Demonstration unit.

SUMMARY OF FINDINGS

1. Thermal Efficiency

There are three methods by which the overall thermal efficiency of the Demonstration units and the Woolfenden units have been compared. The first was a purely theoretical approach, in which the factors considered include the amount of surface area exposed and the resistivity (or R values) of the wall/roof/floor sections used. This approach specifically excludes consideration of variation in use by residents, the efficiency of the heating system, air infiltration, factors of workmanship, site or environmental conditions. The use of this method indicated that the heat loss of the Demonstration unit should be 29% less than that of the 3-bedroom Woolfenden unit (which has the same floor area as the Demonstration unit), or 34% less than the 4-bedroom Woolfenden.

The second approach used was a comparison of actual fuel consumption over a period of several months. Although the consumption figures indicate that the Demonstration units in fact used more fuel than did the control units, the consultants felt that these results did not represent the true situation since the consumption rates were based on the quantity of oil delivered, and since the meters used to measure the oil flow were found to be unreliable when attached to the gravity fed lines of the Demonstration units.

A third method of comparison involved measuring the actual energy consumption of temporary electric heaters during an overnight test period. In this test, the temporary heaters, plus portable fans to distribute the heat within the houses, replaced the permanent heating units of the Demonstration and the Woolfenden houses , thereby eliminating the effect of furnace performance and resulting in a more explicit test of the performance of the envelope. Results indicate an average 14% efficiency advantage for the Demonstration units, less than one-half of the 34% savings which were expected [2]. One likely reason for this difference in performance is that whereas the calculation of

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[2] The slightly larger 4-bedroom Woolfenden units were used for these overnight tests.

theoretical performance was based on the assumption that the windows facing into the sunporch would lose less heat than other windows, the sunporch was in fact very cold (see (7) below) and this increased the rate of heat loss through these windows. Secondly, the consultants suspect that there was a considerable amount of unintended air infiltration and exfiltration through the heat exchanger and the space heater which would have caused a considerable heat loss.

While none of these three methods was in itself satisfactory, the first and third techniques appear to offer a reasonably effective method of evaluation. Even these methods present the problem of noncomparable items since the two unit types differ not only in wall construction, but also in configuration (one versus two storeys) and window areas.

2. Airtightness

The degree of airtightness of both the Demonstration and the Control units was found to be relatively high, as measured by the low tested rate of air infiltration for both types of units compared to current norms. It should be noted that these tests were carried out with the chimney, ducts and the heat exchanger sealed off, whereas during the overnight heat loss tests they were unsealed. Since the heat loss of the Demonstration unit during the overnight test was higher than expected, it appears likely that serious infiltration occurred during this test, probably through the space heater and the heat exchanger. This problem would also partially explain the high rate of fuel consumption during normal operation.

3. Moisture Accumulation

Twelve houses were tested for moisture condensation using probes inserted into several points of the roof and wall envelope. No significant accumulation of moisture was found, probably due to low moisture loads in the house and the higher-than-expected air change rate induced by the space heaters and air-to-air heat exchangers.

4. Performance of Space Heaters

The oil-fired space heaters used in the Demonstration units were found to have an efficiency varying from only 40-70% compared to the 70-80% efficiency of the central heating units in the Control units. This difference constitutes another partial explanation of the high actual fuel consumption of the Demonstration units. The consultants have recommended the installation of an electric fan on the unit to improve its efficiency. If a power interruption were to occur, the fan would of course cease to operate, but the space heater would continue to function, albeit with reduced efficiency. The fan would also reduce the danger of an overheated chimney since the products of combustion would be cooled before entering the flue.

5. Performance of the Heat Exchanger

A reliable air exchange system is essential in a relatively air-tight design such as the Demonstration unit. Air-to-air heat exchangers are in principle a desirable method of providing air exchange, for they can accomplish the twin objectives of providing fresh air and conserving energy.

The units installed do not, however, constitute a fair test of the heat exchanger concept, since they were'not installed as designed and worked so noisily that they had all been shut off. The consultant's tests indicated, not surprisingly,that the units were very inefficient in operation. Models now coming onto the market should prove more satisfactory.

6. Suitability of Non-Electric Water System

The idea of eliminating dependence upon electrical power was admirable. In practice the gravity water feed resulted in less-than-adequate shower performance but this was probably because the position of the water tanks, directly over the bathroom ceiling, did not provide enough head for good pressure.

Although attempts were made to install a hot water heater without electric ignition, none could be found, and this will obviously create a problem during a power outage. It should be noted that although test results indicate that more energy was used to operate the oil-fired water heaters of the Demonstration

units than the all-electric Woolfenden units, the significantly lower cost of oil for the same energy output makes this a worthwhile tradeoff.

7. Stability of Foundations

Although final tests remain to be carried out, preliminary tests indicate that appreciable settlement has occurred only in one corner of one Demonstration house, possibly caused by the loading of the water tank which is located in this area. A follow-up examination of the foundations is planned for the fall of 1982, and this should indicate whether the problem is common to all the Demonstration units.

8. Performance of the Sunporch

The consultants point out that the sunporch, located on the south side of the Demonstration unit, appears to have had little positive effect as an energy saving device, possibly because of the presence of grilles which admit cold outside air into the space for the heat exchanger intake. Despite this limitation the sunporch appears to be well accepted by the residents for its storage and wind buffer functions and its solar gain contribution will presumably become significant during the sunnier spring and fall months.

9. Costs

Although an analysis of costs did not fall within the scope of the consultant's work, some information is available (see Table 2). Of the four communities where comparable information was available, the total estimated construction and erection costs of the Demonstration units were lower than the Woolfenden type in two communities, and higher in the other two settlements. These figures are adjusted for the fact that most of the Woolfenden units built were somewhat larger; but they do not reflect the savings which would accrue if the Demonstration units were to be built in larger numbers, as were the Woolfenden units. Another factor not taken into consideration is the probably higher-than-normal cost of erecting the Demonstration units because of the contractors' inexperience with this type of structure. It therefore seems safe to assume that the total construction cost of Demonstration units will, in the long run, be less than that of the Woolfenden type.

PRELIMINARY CONCLUSIONS

The primary objective of the research was to assess the energy savings which would be enjoyed by the Demonstration houses compared to the Woolfenden houses which were used as controls. The overnight heating tests resulted in a performance difference between the Demonstration and the 4-bedroom Control units of only about 14% instead of the 34% which was expected. A similar difference between actual and expected performance would presumably be found in comparing the Demonstration units with the 3-bedroom Woolfenden units of the same floor area.

The causes of the relatively poor performance are not easy to pinpoint. As previously pointed out, the Demonstration unit appears to have suffered from substantial uncontrolled air infiltration through the heat exchanger and/or the space heater, which would provide a partial explanation. A more complete understanding of the potential performance of the Demonstration unit, however, requires a somewhat theoretical approach.

A direct comparison is difficult since there are several noncomparable features in the two unit types, but the issues can be clarified by reference to Table 3, which indicates the theoretical performance differentials for the 3-bedroom Demonstration and Control units, as well as for some hypothetical versions of both units. The starting point is the expected performance advantage of 29% which would be enjoyed by the Demonstration unit compared to the 3-bedroom Woolfenden unit of the same floor area[3]. The following points illustrate the effect of actual and hypothetical individual design differences between the two unit types:

a) The Demonstration house has 10.75 square metres of window area (including windows facing the sunporch) compared to 5.60 for the Woolfenden unit. Because of the high rate of heat

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[3] Table 3, Unit B versus Unit A

loss through windows, the difference in total performance would be 38% instead of 29% if both units had the same smaller window area but all other differences remained[4].

b) A significant proportion of the theoretical performance difference is accounted for by the two-storey configuration of the Demonstration unit, which has exactly the same floor area as the 3-bedroom Control units, but arranged on two levels. The savings are due to the fact that the ratio of surface area to internal volume for a two-storey is less than that for a one-storey unit, thus exposing less total surface and reducing heat losses.

If the factors of amount of insulation, infiltration and window area were held constant at the level of the Woolfenden unit, then the two-storey configuration alone would result in savings of 11%[5]. If the comparison is made on the basis of both units having the R values, window area and infiltration rates of the Demonstration unit[6], the saving for a two-storey unit rises to about 14%.

c) Another hypothetical comparison can be made which singles out the effect of the different standards of insulation and airtightness of the Demonstration and Woolfenden units. If the factors of configuration and window size are held constant at the level of the Woolfenden unit, ie; if the Woolfenden units were built to the same insulation and vapour barrier standards as the Demonstration units, then a theoretical saving of 26% might be expected compared to the existing Woolfenden units[7]. If the larger window area of the Demonstration unit was assumed, in addition to the high

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[4] Table 3, Unit E versus Unit A

[5] Table 3, Unit F versus Unit A

[6] Table 3, Unit B versus Unit C

[7] Table 3, Unit D versus Unit A

insulation and vapour barrier standards, the savings would drop to 17% over the current Woolfenden model[8].

These points underline the complexity of making valid comparisons where there are so many points of difference. It would appear sensible to state, however, that for the purposes of establishing some useful guidelines for the selection of new housing types the following points should be considered:

Two-storey Configuration

The two-storey house form appears to be a useful housing form in the North. Not only does it conserve energy through its shape, but there are other advantages which were only partially covered in the study. A space heater, for example, can work more efficiently in a two-storey unit than in a single-storey unit, because of the natural convection flow of warmed air to the second floor. If space heaters are desirable because of the independence from power failures which they offer, then the two-storey shape is advantageous.

Another intrinsic advantage of the two-storey is in its greater structural rigidity. Although the final test results of foundation settlement are not available, there is no doubt that it is easier to prevent *differential* settlement in the two-storey box than in a one-storey unit of the same floor area. Finally, the somewhat lower costs of the two-storey units, despite the added insulation and material in the envelope, is presumably a partial reflection of the reduction in envelope area from 389 m^2 to 253 m^2, a saving of 35% for houses of the same floor area.

One possible drawback of two-storey units is the more elaborate measures for exits which must be taken to ensure the safety of second-floor occupants in case of a fire, but this should not present a major roadblock in the adoption of this housing type. The compatability of a two-storey housing form with local preferences is not a question which can be answered on the basis

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[8] Table 3, Unit C versus Unit A

of this research, nor was it intended to be. Very preliminary indications, however, are that the basic two-storey layout is acceptable.

Improved Thermal Performance of Envelope

The performance improvements due to the increased amounts of insulation and improved air tightness appear to be worthwhile from the perspective of energy conservation. The absence of detailed data on construction costs, however, makes a proper cost/benefit assessment impossible, and the suspected air leaks through the heat exchangers and/or space heaters have reduced the value of the field tests as indicators of the energy benefits of the envelope design.

Again referring to the hypothetical variations in Table 3, it is apparent that energy savings in the order of 17% to 25% would be possible if the Woolfenden unit were built with to the same standards of insulation and vapour barriers as the Demonstration units. In a two-storey configuration, the gain in going from Control to Demonstration standards of envelope design should be about 27%, an appreciable benefit[9]. It is evident, however, that moving to a higher standard of envelope design would only be worthwhile if heat exchangers were used which are of higher standards in design and installation than the type currently used.

Sunporch

The sunporch appears to have demonstrated its worth as a storage area and a wind buffer. Based upon the overall thermal performance of the Demonstration units, the contribution of the sunporches was modest; but its performance as a solar heat trap cannot be fairly evaluated on the basis of the minimal hours of sunlight which were available during the test period. It does appear, however, that the open vents in the sunporch wall (to provide air for the heat exchanger) impose a fairly heavy penalty upon its ability to retain any heat gained through insolation.

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[9] Table 3, Unit B versus Unit G

Other Features

The oil-fired space heaters used were extremely inefficient, but with the addition of the circulating fan suggested by the consultants, it may prove to be a form of space heating in two-storey houses which offers a high degree of independence from power outages. The heat exchanger concept is a sensible alternative to windows for the ventilation of airtight houses in the North, and units can be found which will operate efficiently and quietly. The gravity-feed water system did not work properly as designed, but even if a pump is required for fully satisfactory operation, gravity feed can be a useful option during power outages. More work is obviously required to find or design an oil-fired hot water heater which does not require electric ignition and pump, but this also appears to be an achievable goal.

COMPARISON OF DEMONSTRATION AND CONVENTIONAL UNITS TABLE 1

ITEM/ASPECT	KEEWATIN DEMO UNITS (4 tested)	WOOLFENDEN 1980 (7 tested)	WOOLFENDEN 1981 (1 tested)
Household/family size	3 to 6	4 to 7	same as 1980
Basic configuration	Two storey detached, cold porch on south	Bungalow, 3/4 bedrooms, split roofline	same as 1980, but conventional low-pitch roof
Floor area	104 sq.m	104/112 sq. m	104 sq.m
Exposed surface area (Roof + walls + floor)	253 sq. m	389/412 sq. m	330 sq.m +/-
Window area (sq. m)	7.24 plus 3.51 in sunporch	4.97/5.60	4.97
Space heating type	Gravity fed oil space heater Effic. 40-70%	Forced air oil fired furnace Effic. 70-80%	same
Heat Distribution	500 cfm fan from clg. to 2nd floor plenum	Ceiling ducts	Floor ducts
Air exchange	Air to air heat exchanger. Bath + kitchen exh., sunporch intake	Bathroom exhaust, supply by windows	same
Air tightness (tested)	3.0 ach*	average of 2 readings 5.4 ach	
Domestic Hot Water	Oil fired	Electric	Oil fired
Wall construction	Wall truss 300 mm insul. RSI 7.5	Stressed-skin panels RSI 5.1	same
Ceiling/roof construction	Roof truss 400 mm insul. RSI 9.9	Cathedral clg. Split roofline RSI 7.0	Cathedral clg. RSI 8.8
Floor construction	Wood truss 400 mm insul.+ 200 mm airspace RSI 10.1	RSI 8.8	same
Basement/foundations	Glulam beams form sealed space	Wood raft on gravel pad	same, but more clearance under the floor

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* house air changes per hour

COMPARATIVE COSTS OF DEMONSTRATION AND CONVENTIONAL UNITS

TABLE 2

	Demo. Units	Woolfenden	Difference		Comments
			Am't	%	
Rankin Inlet					
Land development	$ NA	$ NA			4 four bedroom Woolfenden units in contract.
Construction + erection:	NA	107,233.			
Land + construction + erection:	100,017.	NA			
Weighted construction + erection [1]		96,510.			
Weighted comparable cost [2]	100,000.	96,500.	+ 3,500.	+3.6%	
Baker Lake					
Land development:	6,200.	NA			4 three bdrm. + 1 four bdrm. Woolfenden units in contract.
Construction + erection:	109,365.	103,796.			
Land + construction + erection:	115,565.	NA			
Weighted construction + erection:		100,680.			
Weighted comparable cost:	109,400.	100,700.	+ 8,700.	+8.6%	
Whale Cove					
Land development	NA	NA			1 three bdrm. + 3 four bdrm. Woolfenden units in contract
Construction + erection:	NA	113,580.			
Land + construction + erection:	97,926.	NA			
Weighted construction + erection:		104,490.			
Weighted comparable cost:	92,050.	104,500.	- 12,450.	-11.9%	
Chesterfield Inlet					
Land development:	NA	NA			4 four bdrm. Woolfenden units in contract
Construction + erection:	NA	105,008.			
Land + construction + erection:	97,421.				
Weighted construction + erection:		94,510.			
Weighted comparable cost:	91,600.	94,500.	- 2,900.	-3.1%	

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[1] **Weighted construction + erection cost** is cost of Woolfenden units adjusted for size differences between 3 and 4 bedroom units.

[2] **Weighted comparable cost** is cost of Demonstration units adjusted for estimated proportion of land development costs (using Baker Lake proportion), and weighted construction + erection cost of Woolfenden units.

TABLE 3

COMPARISONS OF THE THEORETICAL PERFORMANCE OF WOOLFENDEN AND DEMONSTRATION UNITS, ACTUAL AND HYPOTHETICAL CHARACTERISTICS

	AS DESIGNED		HYPOTHETICAL				
	Woolf. "A"	Demo. "B"	Woolf. "C"	Woolf. "D"	Demo. "E"	Demo. "F"	Demo. "G"
Exposed surface area as in Woolfenden	YES		YES	YES			
R values as in Woolfenden	YES					YES	YES
Window area as in Woolfenden	YES			YES	YES	YES	
Air exchange rate as in Woolfenden	YES					YES	YES
Exposed surface area as in Demonstration		YES			YES	YES	YES
R values as in Demonstration		YES	YES	YES	YES		
Window area as in Demonstration		YES	YES				YES
Air exchange rate as in Demonstration		YES	YES	YES	YES		
ANTICIPATED PERFORMANCE Watts/degree C	102.7	72.7	84.9	76.2	64.1	91.2	99.9

Note: YES indicates that the model indicated includes this feature. The five hypothetical versions include various Woolfenden or Demonstration features to permit feature-by-feature comparisons.

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